2100
#5
T3
3/23/00

169.1416 PATENT APPLICATION

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:	Examiner: Not Assigned
CAMERON BOLITHO BROWNE	Group Art Unit: 2772
Application No.: 09/379,729	
Filed: August 24, 1999	
For: METHOD AND APPARATUS FOR TRANSFORMING A SET OF CLOSED CURVES	Date: November 10, 1999

Assistant Commissioner for Patents
Washington, D.C. 20231

CLAIM TO PRIORITY

Sir:

Applicant hereby claims priority under the International Convention and all rights to which he is entitled under 35 U.S.C. § 119 based upon the following Australian Priority Application:

Application No.	Date Filed
PP5577	August 28, 1998

A certified copy of the priority document is enclosed.

Applicant's undersigned attorney may be reached in our New York office by telephone at (212) 218-2100. All correspondence should be directed to our new address given below.

Respectfully submitted,

Attorney for Applicant

Registration No. 29,296

FITZPATRICK, CELLA, HARPER & SCINTO
30 Rockefeller Plaza
New York, New York 10112-3801
Facsimile: (212) 218-2200

AN 09/379,729
GAU 2772

AUSTRALIA

Patent Office
Canberra

I, KIM MARSHALL, MANAGER EXAMINATION SUPPORT AND SALES, hereby certify that the annexed is a true copy of the Provisional specification in connection with Application No. PP 5577 for a patent by CANON KABUSHIKI KAISHA filed on 28 August 1998.

COMMONWEALTH OF AUSTRALIA
AUSTRALIA
PATENT OFFICE

WITNESS my hand this Sixteenth
day of August 1999

KIM MARSHALL
MANAGER EXAMINATION SUPPORT AND
SALES

CERTIFIED COPY OF
PRIORITY DOCUMENT

THIS PAGE BLANK (USPTO)

S & F Ref: 409081

ORIGINAL

AUSTRALIA

Patents Act 1990

PROVISIONAL SPECIFICATION FOR THE INVENTION ENTITLED:

Method and Apparatus for Transforming a Set of Closed Curves

Name and Address of Applicant: Canon Kabushiki Kaisha, incorporated in Japan, of 30-2, Shimomaruko 3-chome, Ohta-ku, Tokyo, 146, JAPAN

Name of Inventor(s) Cameron Bolitho Browne

This invention is best described in the following statement:

5805

METHOD AND APPARATUS FOR TRANSFORMING A SET OF CLOSED CURVES

Field of Invention

The present invention relates to a method and apparatus for transforming a set of closed curves. The invention also relates to a computer program product including a computer readable medium having recorded thereon a computer program for transforming a set of closed curves.

Background of Invention

In the fields of computational geometry and graphics, it is often desirable to modify the shape of an object in some consistent, reproducible and controllable manner, to produce a result that satisfies some criteria regarding shape or form. Such criteria might include the transformation of shapes to those that are considered to be more artistically appealing or complex, but still retain the basic shape of the original outline.

For instance, it may be desirable to transform computer typeface or font defined by character shape outlines to produce more interesting and artistically pleasing results, where the basic overall outline shapes are maintained so that readability is not lost.

The publication United States Patent No. 5,701,404 discloses a method for trimming non-uniform rational B-spline surfaces according to curves projected onto them. However, this method suffers from the disadvantage that the basic overall shape of the original outline is not retained.

Summary of the Invention

It is an object of the present invention to ameliorate one or more disadvantages of the prior art.

One or more exemplary aspects of the invention are listed below, but are not limited thereto.

According to one aspect of the invention there is provided a method for transforming a set of closed first curves defined on a surface, wherein the first curves contain no self-crossover points, the method including the steps of;

(i) providing a pattern including a set of continuous second curves for projection over the set of first curves upon the surface, wherein the second curves contain no self-crossover points;

(ii) determining a set of intersection points of the set of first curves with the set of second curves;

(iii) determining a set of crossover points within the set of intersection points; and

(iv) selecting curve intervals, delimited by the crossover points, from the set of first curves and the set of second curves in accordance with a predetermined rule to form closed loops; wherein the closed loops form said transformed set of closed curves.

According to another aspect of the invention there is provided an apparatus for transforming a set of closed first curves defined on a surface, wherein the first curves contain no self-crossover points, the apparatus including;

providing means for providing a pattern including a set of continuous second curves for projection over the set of first curves upon the surface, wherein the second curves contain no self-crossover points;

a first determining means for determining a set of intersection points of the set of first curves with the set of second curves;

a second determining means for determining a set of crossover points within the set of intersection points; and

a first selecting means for selecting curve intervals, delimited by the crossover points, from the set of first curves and the set of second curves in accordance with a predetermined rule to form closed loops; wherein the closed loops form said transformed set of closed curves.

According to still another aspect of the invention there is provided a computer program product including a computer readable medium having recorded thereon a

computer program for transforming a set of closed first curves defined on a surface, wherein the first curves contain no self-crossover points, the apparatus including;

providing means for providing a pattern including a set of continuous second curves for projection over the set of first curves upon the surface, wherein the second curves contain no self-crossover points;

a first determining means for determining a set of intersection points of the set of first curves with the set of second curves;

a second determining means for determining a set of crossover points within the set of intersection points; and

a first selecting means for selecting curve intervals, delimited by the crossover points, from the set of first curves and the set of second curves in accordance with a predetermined rule to form closed loops; wherein the closed loops form said transformed set of closed curves.

Brief Description of the Drawings

Embodiments of the invention are described with reference to the drawings, in which:

Figs. 1A to 1C illustrate the concept of a crossover point;

Figs. 2A to 2C further illustrate the concept of a crossover point;

Figs. 3A and 3B illustrate the definition of a crossover point, and a special case of crossover;

Fig. 4A illustrates an intersection point that is not a crossover point;

Figs. 4B and 4 C illustrate an example of the of forward and backward direction for a closed curve C;

Fig. 4D illustrates the concept of positive and negative direction for a open continuous curve;

Fig. 5 is a flow diagram of the preferred method for transforming a set of closed curves.

Fig. 6 is a flow diagram showing in more detail the step 510 of Fig. 5

Fig. 7A illustrates the set of closed curves C of character "A";

Fig. 7B illustrates the filled counterpart of Fig. 7A;

Fig. 8 illustrates an example pattern P composed of parallel sinusoidal curves;

Fig. 9A illustrates C' the result of intersecting C of Fig. 7A and P of Fig. 8;

Fig. 9B illustrates the filled counterpart of Fig. 9A;

Figs. 10A illustrates C' the inverted result of intersecting C of Fig. 7A and P of Fig. 8;

Fig. 10B illustrates the filled counterpart of Fig. 10A;

Figs. 11A and 11B illustrate the crossover points and curve intervals formed by the intersection of a closed curve set C and pattern P, and the resulting shape C';

Fig. 12 illustrates an example of null transformed curve set C' from a single pattern P curve intersected with C;

Fig. 13 illustrates an example of a transformed curve set C' from a single pattern P curve intersected with C;

Fig. 14 illustrates another example of a transformed curve set C' from a single pattern P curve intersected with C;

Figs. 15A and 15B illustrate the result of inverting a transformed curve set C';

Fig. 16 illustrates the order of processing for multiple C' regions;

Fig. 17 illustrates the order of processing for multiple C' regions in the presence of a hole;

Figs. 18A to 18C illustrate various transformations that can be achieved using different P base shapes;

Fig. 19 illustrates a transformation utilising a checkerboard effect ;

Fig. 20 illustrates a transformation utilising a gradient effect; and

Fig. 21 is a block diagram of a general purpose computer with which the embodiments can be implemented;

Detailed Description

Preferred Embodiment of Method(s)

Before proceeding with a description of the embodiments, a brief review of terminology used hereinafter is provided.

Figs. 1A to 1C illustrate the concept of the term "crossover point". In Fig. 1A, curves AB 100 and CD 102 do not contain any intersection or crossover points. In Fig. 1B, curves AB 104 and CD 106 intersect at point I 108 but do not crossover. In Fig. 1C, curves AB 110 and CD 112 have two intersection points J 114 and K 116, which are both hereby classed as being crossover points.

This concept is further illustrated in Figs. 2A to 2C, where an identical case is shown for differently shaped curves. In Fig. 2A, curves AB 200 and CD 202 contain no intersection or crossover points. In Fig. 2B, curves AB 204 and CD 206 contain one intersection point I 208 but no crossover points. In Fig. 2C, curves AB 210 and CD 212 contain two intersection points J 214 and K 216, which are both also crossover points.

Fig. 3A illustrates in more formal terms the definition of a "crossover point". Curves AB 300 and CD 302 intersect at point P 304. Examining point O 306 along AB immediately prior to the intersection point P, and point Q 308 along AB immediately following the intersection point P, it is observed that O and Q lie on opposite sides of curve CD, that is, curve AB has "crossed over" curve CD at point P. Similarly, it can be said that curve CD has "crossed over" curve AB. Intersection points exactly define crossover points, but not all intersection points are necessarily crossover points. The complete set of crossover points between a first set of curves C and a second set of curves P is referred to as a crossover set X. A closed curve which crosses over itself and thus intersects itself, is referred to as a self-crossover.

Fig. 3B illustrates a special case of curves EFGH 310 and IJ 312 that share a common interval between points F 314 and G 316. Points F and G and all points with in the interval FG are intersection points. However, there is only one crossover along this interval FG, so a single point from this interval must be chosen to represent the crossover point. To maintain consistency and ensure a reproducible result, the

convention used in the preferred embodiment is that the first point encountered along the shared interval is chosen as the crossover point, point F in this case.

Fig. 4A illustrates the case of an intersection point that is not a crossover point. Curves AB 400 and CD 402 intersect at point P 404. However, in this case it is observed that point O 406 along AB immediately prior to the intersection point P, and point Q 408 along AB immediately following the intersection point P, both lie on the same side of curve CD, that is, curves AB and CD have not crossed over.

Fig. 4B illustrates the concept of positive and negative direction for a open continuous curve. The open continuous curve AB is represented in a parametric form $x=f(t)$, $y=g(t)$ having a parameter t commencing at t_0 and terminating at t_n. The direction from t_0 to t_n along the curve AB is defined as the positive direction where $t_0 \leq t \leq t_n$. The negative direction is defined as that direction along the open curve AB which is opposite to the positive direction. Of course, the actual direction of the positive direction of a curve AB is dependent upon the choice of parametric functions.

Figs. 4C and 4D illustrate an example of the forward and backward direction of a closed continuous curve C. The forward direction of a closed curve C which bounds an object R is defined herein as that direction along the closed curve C which has the object on a specified side. The backward direction of the closed curve C is defined herein as that direction along the closed curve C which has the object on the side opposite to the specified side. In the examples given herein, the specified side is the right hand side. In Fig. 4C, the object R bounded by the curve C is located inside the curve C. Thus the forward direction is along the curve C in the direction t_p to t_q. In Fig. 4D, the same curve C is shown. However, the object R bounded by the curve C is located outside the curve C. Thus, the forward direction in these circumstances is from t_q to t_p. In these examples, it can be seen that the forward direction is in a clockwise direction where the closed curve C bounds the object R within its interior and that the forward direction is in the anti-clockwise direction where the closed curve C bounds the object R on its exterior. Alternatively, the specified side may be chosen as the left hand side. In this case, the forward directions of Figs. 4C and 4D are consequently

reversed. Whatever alternative is chosen, it should be used consistently throughout the preferred method to ensue reproducibility.

Now turning to Fig. 5, there is illustrated a flow diagram of the preferred method for transforming a set of closed first curves defined on a surface. The preferred method is described with reference to 2-dimensional examples, in particular the orientation of 2-dimensional curves that describe the paths of stroke-based typeface characters. However, the principles of this invention have general applicability to n-dimensional space curves and are not intended to be limited to 2-dimensional curves only.

In step 500 of the preferred method, the process commences and a set of closed first curves defined on a 2-dimensional planar surface is inputted. Alternatively, the set of closed first curves may be defined on a 3-dimensional surface, where a 3-dimensional effect is desired. Figs. 7A and 7B illustrate a typical example of a set of closed first curves. Specifically, Fig. 7A illustrates a character glyph of a font described by its outline path 700. Fig. 7B illustrates its filled counterpart that describes a region R 704 enclosed by the outline path 700. In Figs. 7A and 7B the outline path 700 describes a set of curves C, which are continuous closed curves that contain no self-crossovers. The set of curves may include holes in the outline shape 702, typically represented in industry standard typefaces by curves oriented in the opposite direction to exterior curves. The shape of C dictates the overall shape of the transformed result.

In step 502, a pattern including a set of second curves is generated in response to user input 504. Fig. 8 illustrates a typical example of a pattern including a set of second curves that lie on the same surface as C, and constitute such a pattern P 800. The constituent curves of P may be open-ended, but within the region R they are continuous and contain no self-crossovers or intersections between members of P. The pattern P may be a generated by an implicit function, and parameterized to describe characteristics such as base shape, period, amplitude, gradient, and so on. The pattern P need only be generated for the region R, increasing efficiency. Alternatively, the pattern P may be retrieved from storage means.

In the next step 506, the intersection points of the set of first curves C and the set of second curves P are determined. The intersection step can be performed efficiently through the use of standard computational methods such as local neighborhood search, or ordering curve segments by coordinate and performing scanline traversal. Fig. 11A illustrates the intersections of a set of closed first curves C and a set of pattern curves P. Specifically, Fig. 11A shows one closed curve C 1100 and a set of pattern curves P composed of curves P_1 1102 and P_2 1104. In the step 506, firstly all the intersection points X_1,X_2,X_3 and X_4 between C and P are determined.

In the next step 508, a set of crossover points X is determined from the set of intersection points. In this step 508, each intersection point is tested for crossover, resulting in the crossover point set X composed of X_1 1106, X_2 1108, X_3 1110 and X_4 1112. As the curve C is continuous, closed, and contains no self-crossovers, and as the curves P are continuous and contain no self-crossovers within the region R of the closed curve C, then the crossover point set X will always contain an even number of crossover points, as any crossover entering R must have a corresponding crossover leaving R.

In the next step 510, the transformed curve set C' 1122 shown in Fig. 11B is constructed by assembling closed loops of intervals along C and P delimited by crossover points X_n. For instance, the transformed curve set C' 1122 is assembled from the following curve intervals:

a) interval 1114 along C between X_1 and X_2,

b) interval 1116 along P between X_2 and X_3,

c) interval 1118 along C between X_3 and X_4,

d) interval 1120 along P between X_4 and X_1.

Curve intervals are directed according to crossover point ordering, and adjacent intervals are joined at crossover points. The complete loop returns to the start point X_1, reclosing the transformed curve. This example results in a transformed curve set C' 1122 with a single closed curve member, however multiple C' members may as

easily be obtained, and there is not necessarily any correspondence between the cardinality of C and the cardinality of C'.

In step 512, the transformed closed set of curves are displayed on a monitor and/or printed. Afterwards, the processing terminates at step 514.

Turning now to Fig. 6, there is shown the step 510 of Fig. 5 in more detail. In step 610, all the crossover points within the set of crossover points X are ordered in accordance with a predetermined order. The ordering of crossover points within X is independent of intersection point ordering. In the preferred embodiment, crossover points are ordered according to their position along C in a clockwise direction (note that each crossover member of X has a defined position along both P and C) to ensure consistency and reproducibility.

In step 611, the transformed curve set C' is set to empty and all the crossover points Xn are marked as "unvisited". In step 612, the set of crossover points is examined in order, and a new transformed curve is started at an "unvisited" crossover point X_1, that is highest in the order. This "unvisited" crossover is then marked as "visited".

In decision block 614, a check is made to determine whether or not the crossover point last marked as "visited" is the first crossover point X_1 in the current closed loop. If decision block 614 returns false (No), then processing continues at step 622. Otherwise processing continues at step 616. In step 616, the first curve interval of the current loop selected, delimited by crossover points. This selection process 616 selects the curve interval along C that commences at the first crossover point X_1 and that proceeds in the forward direction and terminates at the next adjacent unmarked crossover point X_2. In the next step 618, the terminating crossover point X_2 is marked as "visited".

In the decision block 620, a check is made whether or not a closed loop has been formed. This is determined by checking whether the last mentioned terminating crossover point X_n is the same as the first crossover point X_1. If the decision block 620

returns true (Yes), then processing continues at step 625. Otherwise processing continues at decision block 614.

If decision block 614 returns false, namely when the last marked crossover point is not the first crossover point X_1 in the closed loop, then processing continues at step 622. In step 622, the next curve interval in the current loop is selected delimited by crossover points. This selection process 622 selects the curve interval along C or P that commences at the last marked terminating crossover point and terminates at an unmarked adjacent crossover point. This selection process 622 can thus chose the next curve interval from the four curve intervals available. The selection process selects the first interval encountered around the last marked terminating crossover point in the anticlockwise direction. In the next step 624, the unmarked adjacent crossover point of the selected interval is marked as "visited" and the processing continues at decision block 620. If the decision block 620 determines a closed loop has been formed, then the processing continues at step 625. Otherwise the steps 614,622,624 and 620 continue until the transformed loop is formed. In step 625, the transformed closed curve is added to the transformed curve set C '.

Given that crossover points by definition result in intervals belonging to alternating curve sets (C, P, C, P and so on) around any crossover point X_n, then the first interval encountered around X_2 in the anticlockwise direction must belong to P. Also, intervals along C will always be followed in the forward direction, however, intervals along P may be followed in either the positive or negative directions. During the first pass of step 622 the interval X_2X_3 will be selected. The next interval selected by step 622 is interval X_3X_4. Arriving at X_4, the first interval in anticlockwise order belongs to P, and thus the next pass of step 622 selects interval X_4X_1. As the next crossover point X_n is X_1, the curve's starting point, a complete loop has been traversed and the curve is closed and added to the transformed curve set C'. Each terminating crossover point X_n is marked as "visited" once a curve interval has been selected and processed.

In the decision block 626, a check is made whether or not all closed loops have been formed. This is preferably determined by checking whether all the crossover points X_n are marked as "visited". If the decision block 626 returns true (Yes), then processing continues at step 512 and the transformed curve set C ' is complete. Otherwise the processing is returned to decision block 614.

The preferred method has the advantage that it is applicable to general surfaces, and assumes minimal dependency between the source and target curve sets, beyond their existing on the same surface. The transformation may be safely applied to arbitrary outline shapes provided that they have no self-crossovers.

Moreover, the transformation process is consistent, reproducible and controlled so that it can be applied to any outline shape, without the need for intervention by the user beyond the setting of certain parameters. The pattern curve set may be defined implicitly, and calculated on demand to fit the region occupied by the source curve set.

In addition, the transformed curve set is preferably alternating, in the sense that neighboring closed regions may touch at common points but do not overlap or intersect. Consequently, a regularly spaced pattern set will result in a set of regularly spaced closed curves alternating with regularly spaced vacant areas. This allows artistic effects such as striping, gradient and checkerboard to be applied to outline shapes.

Examples

The following examples are simply provided for illustrative purposes of the preferred method and other closed curve sets C and patterns P can be employed without departing from the scope and spirit of the invention.

Fig. 9A shows the result of the implementation of the preferred method on the text characters shown in Fig. 7A using the pattern shown in Fig. 8. Specifically, Fig. 9A shows the result of transforming the curve set C 700 with the pattern P 800, giving the transformed curve set C ' 900. The transformed curve set C ' 900 encloses a region R ' 902. In Fig. 9B, this region R ' may be filled resulting in filled regions 904

which alternate with vacant areas 906. These filled regions do not overlap or intersect with other filled regions, but may share common points.

Shown in Figs. 10A and 10B are inverted transformed curve sets Ci' 1000 created by transforming curve set C 700 with the pattern set P 800. The filled region Ri' enclosed by Ci' 1000 is shown as 1004. It can be seen that filled regions 904 described by C' become vacant areas in Ci' 1006, and that vacant areas 906 described by C' 900 become filled areas 1004 in Ci' 1000. Again, filled regions 1004 do not overlap or intersect with each, but may share common points.

Turning now to Fig. 12, there is shown non-intersecting first curve sets C 1202 and P 1200 that result in the empty curve set C' following transformation. As there are no intersection points, there can be no crossover points, and therefore no new transformed curves are assembled.

Fig. 13 shows intersecting curve sets C 1300 and P 1302 that result in a transformed curve set C' with a single member 1304. This is similar to the result illustrated in Fig. 11A.

Turning now to Fig. 14, there is shown intersecting curve sets C 1400 and P 1402 that result in a transformed curve set C' with multiple members 1404 & 1406. Note that in all three cases shown in Figs. 12 to 14 the curve sets C and P are similar but are in different relationships to each other, giving markedly different transformation results.

In the example illustrated in Fig. 14, the crossover point X_1 1408 is examined first, and the interval X_1X_2 along C is traversed. At X_2 1410 the interval X_2X_1 along P is chosen, leading back to the starting point X_1 and closing the transformed curve 1416 that is added to C'. At this stage X_1 has been examined as a candidate for a new transformed curve, and X_1 and X_2 have been visited. X_2 is examined next, but is ignored as it has already been visited.

The crossover point X_3 1412 is next examined and is found to be unvisited. A new transformed curve is started at X_3, and the interval X_3X_4 along C is traversed. At X_4 1414 the interval X_4X_3 along P is chosen, leading back to this transformed curve's

starting point and closing the transformed curve 1418 that is added to C'. At this stage X_1, X_2 and X_3 have been examined as candidates for new transformed curves, and X_1, X_2, X_3 and X_4 have been visited. X_4 is examined next, but is ignored as it has already been visited, and the transformed curve set C' is complete.

Figs. 15A and 15B demonstrate that the cardinality of C' and the cardinality of Ci' are not necessarily the same. The same curve set C 1500 and pattern set P 1502 is used in both cases, but C' yields a transformed curve set with two members curves 1504 and 1506, while the inverted transformed curve set Ci' has only one member 1508.

Fig. 16 illustrates the complete transformation process of curve set C 1600 and pattern set P composed of curves P_1 1602, P_2 1604, P_3 1606 and P_4 1608 into the transformed curve set C' composed of two curves 1612 and 1610. Following the intersection of C with P, the following crossover point set X is obtained and ordered as follows in the forward direction around C: X_1 1614, X_2 1616, X_3 1618, X_4 1620, X_5 1622, X_6 1624, X_7 1626 and X_8 1628. The transformed curves are assembled in the following order:

a) interval X_1X_2 1630,

b) interval X_1X_7 1632,

c) interval X_7X_8 1634,

d) interval X_8X_1 1636,

e) interval X_3X_4 1638,

f) interval X_4X_5 1640,

g) interval X_5X_6 1642,

h) interval X_6X_3 1644,

Following which two new transformed curves 1610 and 1612 have been added to C' and all the crossover points X_n have been visited.

Fig. 17 illustrates the behaviour of the transformation process in the presence of holes. Curve set C consists of two distinct non-intersecting curves 1700 and 1702. The interior curve C_2 1702 has a forward direction opposite to that of the exterior curve

C_1 1700 and defines a hole in region R. The pattern curve set P consists of three distinct non-intersecting curves P_1 1704, P_2 1706 and P_3 1708. P_3 is closed and totally contained within the region bounded by exterior curve C_1, but is valid as it is continuous within R, and does not intersect itself or any other member of P. In this example, the crossover points are ordered in a clockwise direction around C_1 and in an anticlockwise direction around C_2, and thus form the ordered set X_1 1710, X_2 1712, X_3 1714, X_4 1714, X_5 1716, X_6 1718, X_7 1720, X_8 1722, X_9 1724 and X_{10} 1726. Starting at the first point X_1 a new transformed curve C_1' 1728 is created, and is assembled in the following order:

a) interval X_1X_2 along C_1,

b) interval X_2X_3 along P_2,

c) interval X_3X_4 along C_1,

d) interval X_4X_5 along P_2,

e) interval X_5X_6 along C_1,

f) interval X_6X_8 along P_1,

g) interval X_8X_9 along C_2,

h) interval X_9X_1 along P1.

The next unvisited point in the ordered set X is X_7, from which a new transformed curve C_2' 1730 is assembled. In this case, the forward interval along C_2 X_7X_8 leads to a visited point X_8, so the method backtracks to the C_2 point immediately prior to X_7, which in this case is the crossover point X_{10}. The crossover point X_{10} is now treated as the starting point for C_2', and the method proceeds as for the usual case. C_2' is assembled in the following order:

a) interval $X_{10}X_7$ along C_2,

b) interval X_7X_{10} along P_3.

Following this all points X have been visited and the transformed curve set C' is complete.

By way of further example, Figs. 18A to 18C illustrate various transformations of the curve set C 1800 with pattern sets composed of different base shapes. The

transformed curve set C' 1802 shows the transformation resulting from a pattern set derived from a triangular wave shape. The transformed curve set C' 1804 shows the transformation resulting from a pattern set derived from a square wave shape.

Fig. 19 illustrates a further transformation of the curve set C 1800 (Fig 18A). The transformed curve set C' 1900 shows a checkerboard effect. The checkerboard effect is achieved during the filling operation and is not part of the transformation as such.

Fig. 20 illustrates a further transformation of the curve set C 1800 (Fig. 18A). The transformed curve set C' 2000 shows a gradient effect. The gradient is applied during the generation of the pattern set P and is not part of the transformation as such.

Preferred Embodiment of Apparatus(s)

The preferred method is preferably practiced using a conventional general-purpose computer, such as the one shown in Fig. 21, wherein the processes of Figs. 5 and 6 may be implemented as software executing on the computer. In particular, the steps of the method are effected by instructions in the software that are carried out by the computer. The software may be divided into two separate parts; one part for carrying out the transformation method; and another part to manage the user interface between the latter and the user. The software may be stored in a computer readable medium, including the storage devices described below, for example. The software is loaded into the computer from the computer readable medium, and then executed by the computer. A computer readable medium having such software or computer program recorded on it is a computer program product. The use of the computer program product in the computer preferably effects an advantageous apparatus for transforming a set of closed first curves defined on a surface in accordance with the embodiments of the invention.

The computer system 2100 consists of the computer 2102, a video display 2116, and input devices 2118, 2120. In addition, the computer system 2100 can have any of a number of other output devices including line printers, laser printers, plotters, and

other reproduction devices connected to the computer 2102. The computer system 2100 can be connected to one or more other computers via a communication interface 2108c using an appropriate communication channel 2130 such as a modem communications path, a computer network, or the like. The computer network may include a local area network (LAN), a wide area network (WAN), an Intranet, and/or the Internet

The computer 2102 itself consists of a central processing unit(s) (simply referred to as a processor hereinafter) 2104, a memory 2106 which may include random access memory (RAM) and read-only memory (ROM), input/output (IO) interfaces 2108a, 2108b & 2108c, a video interface 2110, and one or more storage devices generally represented by a block 2112 in Fig. 21. The storage device(s) 2112 can consist of one or more of the following: a floppy disc, a hard disc drive, a magneto-optical disc drive, CD-ROM, magnetic tape or any other of a number of non-volatile storage devices well known to those skilled in the art. Each of the components 2104 to 2112 is typically connected to one or more of the other devices via a bus 2114 that in turn can consist of data, address, and control buses.

The video interface 2110 is connected to the video display 2116 and provides video signals from the computer 2102 for display on the video display 2116. User input to operate the computer 2102 can be provided by one or more input devices 2108b. For example, an operator can use the keyboard 2118 and/or a pointing device such as the mouse 2120 to provide input to the computer 2102.

The system 2100 is simply provided for illustrative purposes and other configurations can be employed without departing from the scope and spirit of the invention. Exemplary computers on which the embodiment can be practiced include IBM-PC/ATs or compatibles, one of the Macintosh (TM) family of PCs, Sun Sparcstation (TM), or the like. The foregoing is merely exemplary of the types of computers with which the embodiments of the invention may be practiced. Typically, the processes of the embodiments, described hereinafter, are resident as software or a program recorded on a hard disk drive (generally depicted as block 2112 in Fig. 21) as

the computer readable medium, and read and controlled using the processor 2104. Intermediate storage of the program and pixel data and any data fetched from the network may be accomplished using the semiconductor memory 2106, possibly in concert with the hard disk drive 2112.

In some instances, the program may be supplied to the user encoded on a CD-ROM or a floppy disk (both generally depicted by block 2112), or alternatively could be read by the user from the network via a modem device connected to the computer, for example. Still further, the software can also be loaded into the computer system 2100 from other computer readable medium including magnetic tape, a ROM or integrated circuit, a magneto-optical disk, a radio or infra-red transmission channel between the computer and another device, a computer readable card such as a PCMCIA card, and the Internet and Intranets including email transmissions and information recorded on websites and the like. The foregoing is merely exemplary of relevant computer readable mediums. Other computer readable mediums may be practiced without departing from the scope and spirit of the invention.

Applications

The preferred embodiment has many areas of application and a number of examples follow but are not seen as exhaustive. One application is the use of the preferred embodiment in the generation of different typefaces or fonts. Another application of the preferred embodiment is in the generation of patterns on objects in digital videos for special effects.

The foregoing only describes a small number of embodiments of the present invention, however, modifications and/or changes can be made thereto by a person skilled in the art without departing from the scope and spirit of the invention.

The following numbered paragraphs set forth aspects of the invention, including

1. A method for transforming a set of closed first curves defined on a surface, wherein the first curves contain no self-crossover points, the method including the steps of;

(i) providing a pattern including a set of continuous second curves for projection over the set of first curves upon the surface, wherein the second curves contain no self-crossover points;

(ii) determining a set of intersection points of the set of first curves with the set of second curves;

(iii) determining a set of crossover points within the set of intersection points; and

(iv) selecting curve intervals, delimited by the crossover points, from the set of first curves and the set of second curves in accordance with a predetermined rule to form closed loops; wherein the closed loops form said transformed set of closed curves.

2. A method as set forth in paragraph 1, wherein said step (iv) includes the substeps of:

(iv)(1) ordering all the crossover points in accordance with a predetermined order;

(iv)(2) marking one of said crossover points that is highest in the order and that has not been previously marked;

(iv)(3) determining, if a last marked crossover point is a first point in a said closed loop, and if so:

(iv)(3)(i) selecting one of said curve intervals starting at said first point and terminating at an unmarked crossover point; and

(iv)(3)(ii) marking the terminating crossover point of said one curve interval;

or if not:

(iv)(3)(iii)selecting a further said curve interval starting at the previous said terminating crossover point and terminating at an unmarked crossover point; and

(iv)(3)(iv)marking the current terminating crossover point of said further curve interval;

(iv)(4) repetitively performing the substep (iv)(3) until said closed loop is formed; and

(iv)(5) repetitively performing the substeps (iv)(2) to (iv)(4) until all possible closed loops have been formed.

3. A method as set forth in paragraph 2, wherein said substep (iv)(3)(i) includes selecting a further said curve intervals from the set of first curves, which said one curve interval starts at a said first point and continues in a first direction and terminates at the next adjacent unmarked crossover point.

4. A method as set forth in paragraph 2 or 3, wherein said substep (iv)(3)(iii) includes selecting a said curve interval from the set of first or second curves, which selected curve interval is the first of said curve intervals located in a second direction from the previously selected curve interval and which selected curve interval continues in a third direction and terminates at the next adjacent unmarked crossover point.

5. A method as set forth in paragraph 2,3 or 4, wherein said substep of ordering said crossover points includes ordering the crossover points according to their position along the set of first curves in a fourth direction.

6. A method as set forth in paragraph 5, wherein said first direction and fourth direction are in the forward direction and said third direction is either in the positive or negative direction and said second direction is the backward direction.

7. A method as set forth in paragraph 5, wherein said first direction and fourth direction are in the backward direction and said third direction is either in the positive or negative direction and said second direction is the forward direction.

8. A method as set forth in any one of the preceding paragraphs, wherein said surface is a 2-dimensional surface.

9. A method as set forth in any one of paragraphs 1 to 7, wherein said surface is a 3-dimensional surface.

10. A method as set forth in any one of the preceding paragraphs, wherein said step of selecting curve intervals includes the substep of filling the closed loops with a predetermined color.

11. A method as set forth in any one of the preceding paragraphs, wherein said step of providing a pattern, includes the substep of:

generating said pattern.

12. A method as set forth in any one of the preceding paragraphs 1 to 10, wherein said step of providing a pattern, includes the substep of:

accessing said pattern from storage.

13. A method as set forth in any one of the preceding paragraphs, wherein said step of providing a pattern, includes the substep of:

selecting one of many said patterns in response to user input.

14. A method as set forth in paragraph 11, wherein said generating step includes inputting parameters.

15. A method as set forth in paragraph 14, wherein said input parameters include one or more of the following; base shapes of the patterns, period of the patterns, or amplitude of the patterns.

16. A method as set forth in 15, wherein the amplitude of the pattern varies throughout the pattern.

17. A method as set forth in any one of the preceding claims, wherein the set of first curves constitutes a character glyph of a font.

18. An apparatus for transforming a set of closed first curves defined on a surface, wherein the first curves contain no self-crossover points, the apparatus including;

providing means for providing a pattern including a set of continuous second curves for projection over the set of first curves upon the surface, wherein the second curves contain no self-crossover points;

a first determining means for determining a set of intersection points of the set of first curves with the set of second curves;

a second determining means for determining a set of crossover points within the set of intersection points; and

a first selecting means for selecting curve intervals, delimited by the crossover points, from the set of first curves and the set of second curves in accordance with a predetermined rule to form closed loops; wherein the closed loops form said transformed set of closed curves.

19. An apparatus as set forth in paragraph 18, wherein said first selecting means includes:

ordering means for ordering all the crossover points in accordance with a predetermined order;

a first marking means for marking one of said crossover points that is highest in the order and that has not been previously marked;

a second selecting means for selecting one of said curve intervals starting at a first point and terminating at an unmarked crossover point;

a second marking means for marking the terminating crossover point of said one curve interval;

a third selecting means for selecting a said curve interval starting at the previous said terminating crossover point and terminating at an unmarked crossover point;

a third marking means for marking the current terminating crossover point of said one curve interval;

a third determining means for determining, if a last marked crossover point is the first point in a said closed loop, and if so performing the operations of the second selecting means and the second marking means, or if not, performing the operations of the third selecting means and third marking means;

means for repetitively performing the operations of the third determining means until said closed loop is formed; and

means for repetitively performing the operations of first marking means and third determining means until all possible closed loops have been formed.

20. An apparatus as set forth in paragraph 19, wherein said second selecting means selects one of said curve intervals from the set of first curves, which said one curve interval starts at a said first point and continues in a first direction and terminates at the next adjacent unmarked crossover point.

21. An apparatus as set forth in paragraph 19 or 20, wherein said third selecting means selects a further said curve interval from the set of first or second curves, which selected curve interval is the first of said curve intervals located in a second direction from the previously selected curve interval and which selected curve interval continues in a third direction and terminates at the next adjacent unmarked crossover point.

22. An apparatus as set forth in paragraph 19, 20 or 21, wherein said ordering means orders the crossover points according to their position along the set of first curves in a fourth direction.

23. An apparatus as set forth in paragraph 22, wherein said first direction and fourth direction are in the forward direction and said third direction is either in the positive or negative direction and said second direction is the backward direction.

24. An apparatus as set forth in paragraph 22, wherein said first direction and fourth direction are in the backward direction and said third direction is either in the positive or negative direction and said second direction is the forward direction.

25. An apparatus as set forth in any one of the preceding paragraphs 18 to 24, wherein said surface is a 2-dimensional surface.

26. An apparatus as set forth in any one of the preceding paragraphs 18 to 24, wherein said surface is a 3-dimensional surface.

27. An apparatus as set forth in any one of the preceding paragraphs 18 to 26, wherein said first selecting means includes means for filling the closed loops with a predetermined color.

28. An apparatus as set forth in any one of the preceding paragraphs 18 to 27, wherein said providing means includes means for generating said pattern.

29. An apparatus as set forth in any one of the preceding paragraphs 18 to 27, wherein said providing means includes means for accessing said pattern from storage.

30. An apparatus as set forth in any one of the preceding paragraphs 18 to 29, wherein said providing means includes means for selecting one of many said patterns in response to user input.

31. An apparatus as set forth in paragraph 28, wherein said generating means includes means for inputting parameters.

32. An apparatus as set forth in paragraph 31, wherein said input parameters include one or more of the following; base shapes of the patterns, period of the patterns, or amplitude of the patterns.

33. An apparatus as set forth in 32, wherein the amplitude of the pattern varies throughout the pattern.

34. An apparatus as set forth in any one of the preceding claims 18 to 33, wherein the set of first curves constitutes a character glyph of a font.

35. A computer program product including a computer readable medium having recorded thereon a computer program for transforming a set of closed first curves defined on a surface, wherein the first curves contain no self-crossover points, the apparatus including;

providing means for providing a pattern including a set of continuous second curves for projection over the set of first curves upon the surface, wherein the second curves contain no self-crossover points;

a first determining means for determining a set of intersection points of the set of first curves with the set of second curves;

a second determining means for determining a set of crossover points within the set of intersection points; and

a first selecting means for selecting curve intervals, delimited by the crossover points, from the set of first curves and the set of second curves in accordance with a predetermined rule to form closed loops; wherein the closed loops form said transformed set of closed curves.

36. A computer program product as set forth in paragraph 35, wherein said first selecting means includes:

ordering means for ordering all the crossover points in accordance with a predetermined order;

a first marking means for marking a said crossover point that is highest in the order and that has not been previously marked;

a second selecting means for selecting a said curve interval starting at a first point and terminating at an unmarked crossover point;

a second marking means for marking the terminating crossover point;

a third selecting means for selecting a said curve interval starting at the previous said terminating crossover point and terminating at an unmarked crossover point;

a third marking means for marking the current terminating crossover point;

a third determining means for determining, if the last marked crossover point is the first point in a said closed loop, and if so performing the operations of the second selecting means and the second marking means, or if not, performing the operations of the third selecting means and third marking means;

means for repetitively performing the operations of the third determining means until said closed loop is formed; and

means for repetitively performing the operations of first marking means and third determining means until all possible closed loops have been formed.

37. A computer program product as set forth in paragraph 36, wherein said second selecting means selects a said curve interval from the set of first curves, which said

curve interval starts at a said first point and continues in a first direction and terminates at the next adjacent unmarked crossover point.

38. A computer program product as set forth in paragraph 36 or 37, wherein said third selecting means selects a said curve interval from the set of first or second curves, which selected curve interval is the first of said curve intervals located in a second direction from the previously selected curve interval and which selected curve interval continues in a third direction and terminates at the next adjacent unmarked crossover point.

39. A computer program product as set forth in paragraph 36, 37 or 38, wherein said ordering means orders the crossover points according to their position along the set of first curves in a fourth direction.

40. A computer program product as set forth in paragraph 39, wherein said first direction and fourth direction are in the forward direction and said third direction is either in the positive or negative direction and said second direction is the backward direction.

41. A computer program product as set forth in paragraph 39, wherein said first direction and fourth direction are in the backward direction and said third direction is either in the positive or negative direction and said second direction is the forward direction.

42. A computer program product as set forth in any one of the preceding paragraphs 35 to 41, wherein said surface is a 2-dimensional surface.

43. A computer program product as set forth in any one of the preceding paragraphs 35 to 41, wherein said surface is a 3-dimensional surface.

44. A computer program product as set forth in any one of the preceding paragraphs 35 to 43, wherein said first selecting means includes means for filling the closed loops with a predetermined color.

45. A computer program product as set forth in any one of the preceding paragraphs 35 to 44, wherein said providing means includes means for generating said pattern.

46. A computer program product as set forth in any one of the preceding paragraphs 35 to 44, wherein said providing means includes means for retrieving said pattern from storage.

47. A computer program product as set forth in any one of the preceding paragraphs 35 to 46, wherein said providing means includes means for selecting one of many said patterns in response to user input.

48. A computer program product as set forth in paragraph 45, wherein said generating means includes means for inputting parameters.

49. A computer program product as set forth in paragraph 48, wherein said input parameters include one or more of the following; base shapes of the patterns, period of the patterns, or amplitude of the patterns.

50. A computer program product as set forth in 49, wherein the amplitude of the pattern varies throughout the pattern.

51. A computer program product as set forth in any one of the preceding claims 35 to 50, wherein the set of first curves constitutes a character glyph of a font.

Dated 28 August, 1998
Canon Kabushiki Kaisha

Patent Attorneys for the Applicant/Nominated Person
SPRUSON & FERGUSON

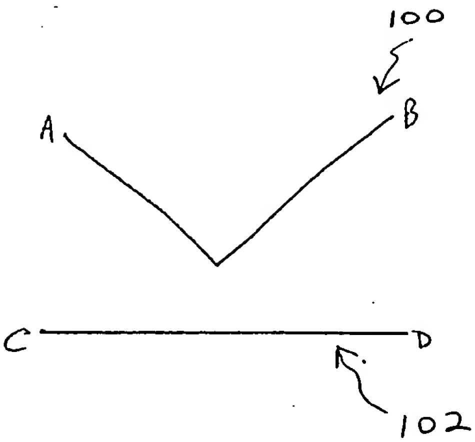


FIG. 1A

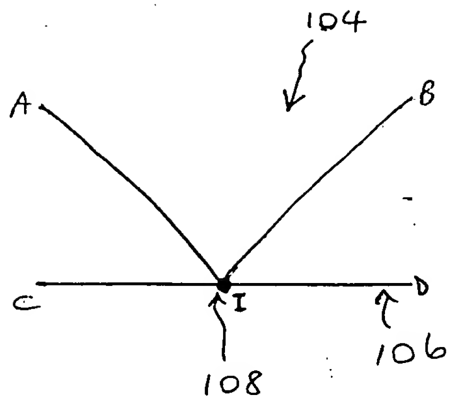


FIG. 1B

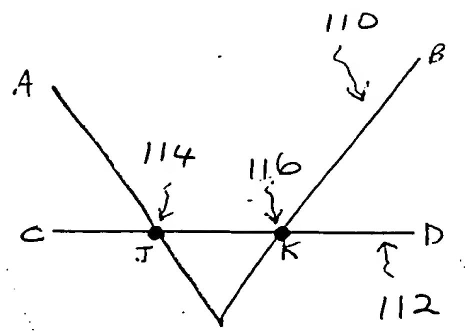


FIG. 1C

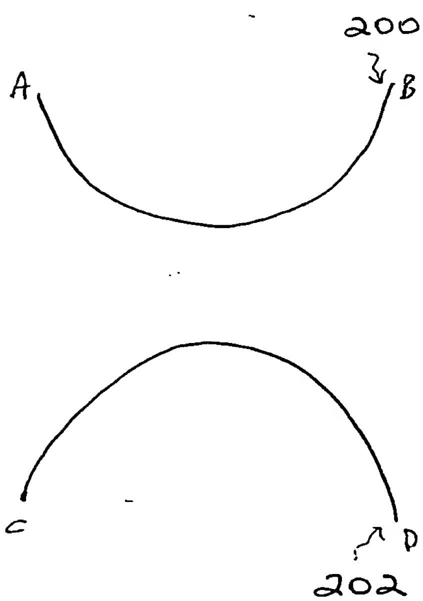


FIG. 2A

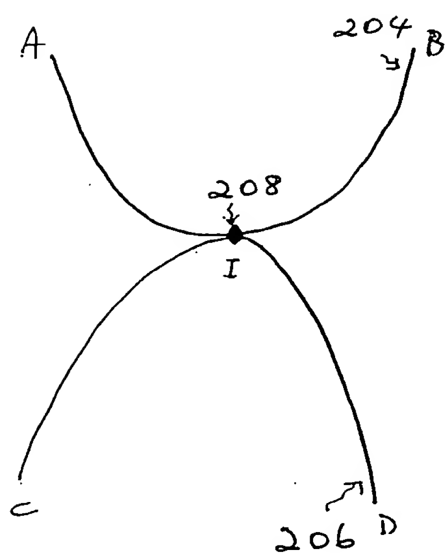


FIG. 2B

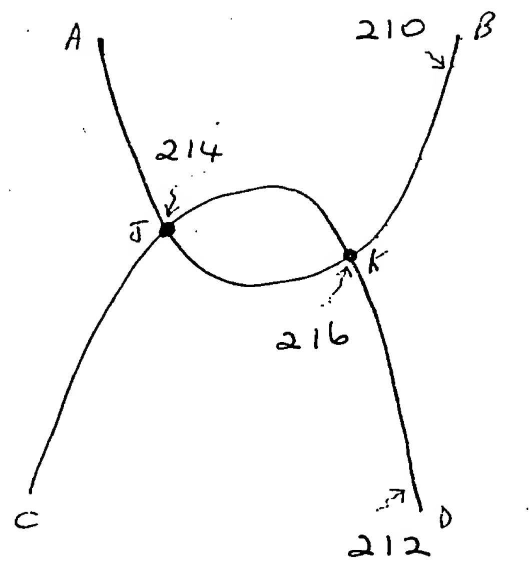
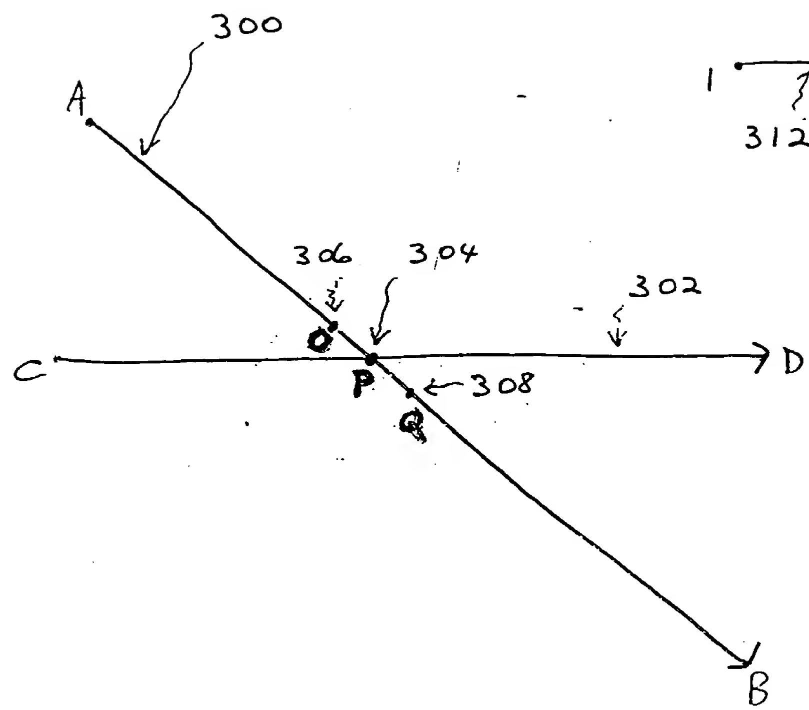


FIG. 2C

FIG. 3A



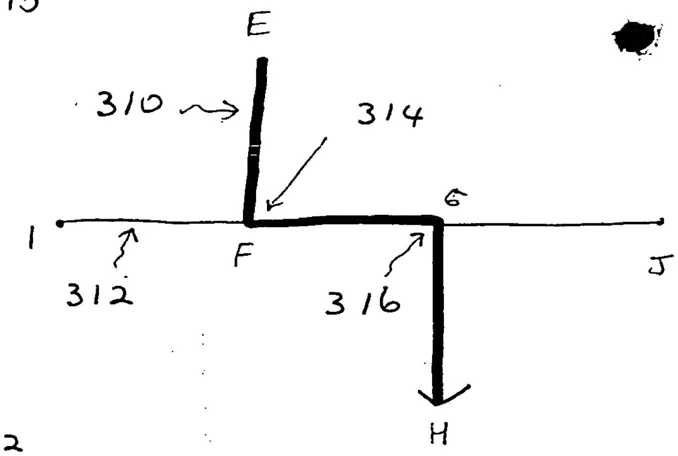
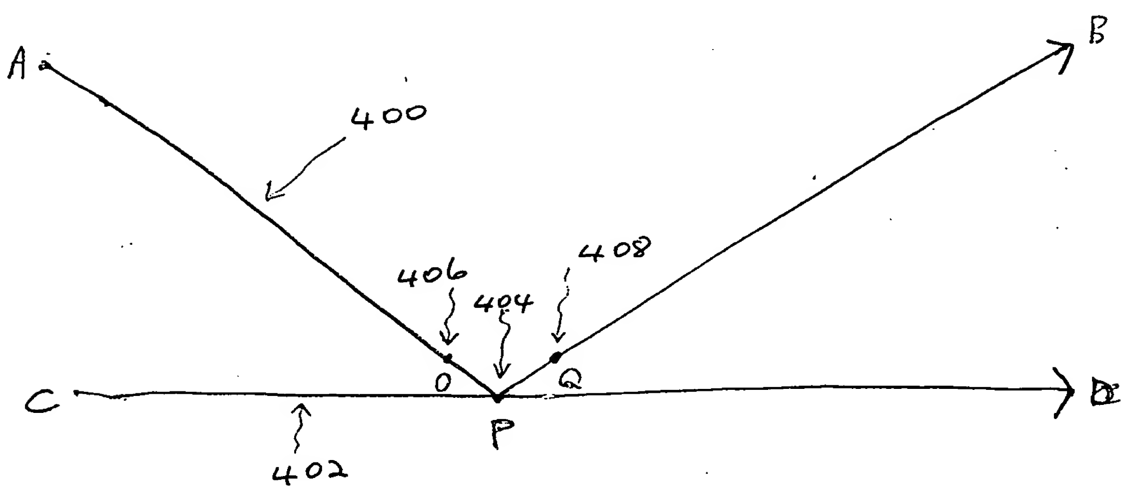


FIG. 3B

Fig. 4A



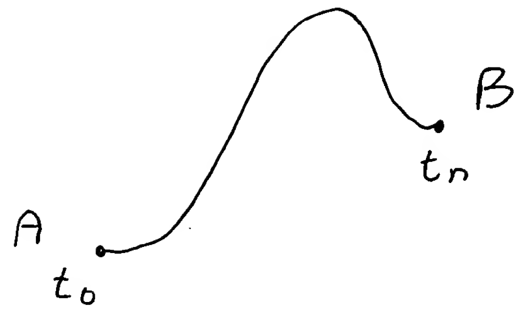


Fig. 4B

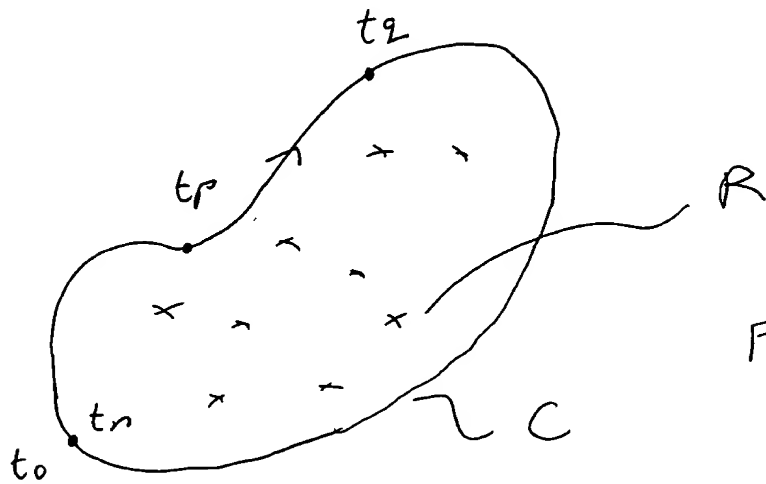


Fig. 4C

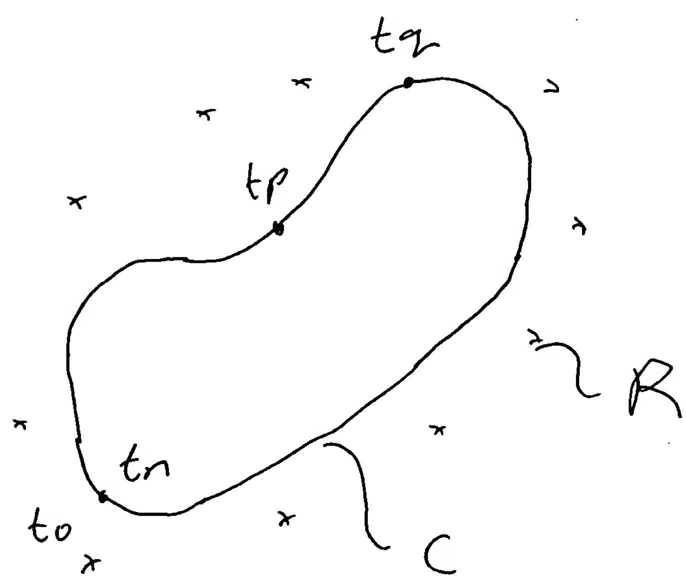


Fig 4D

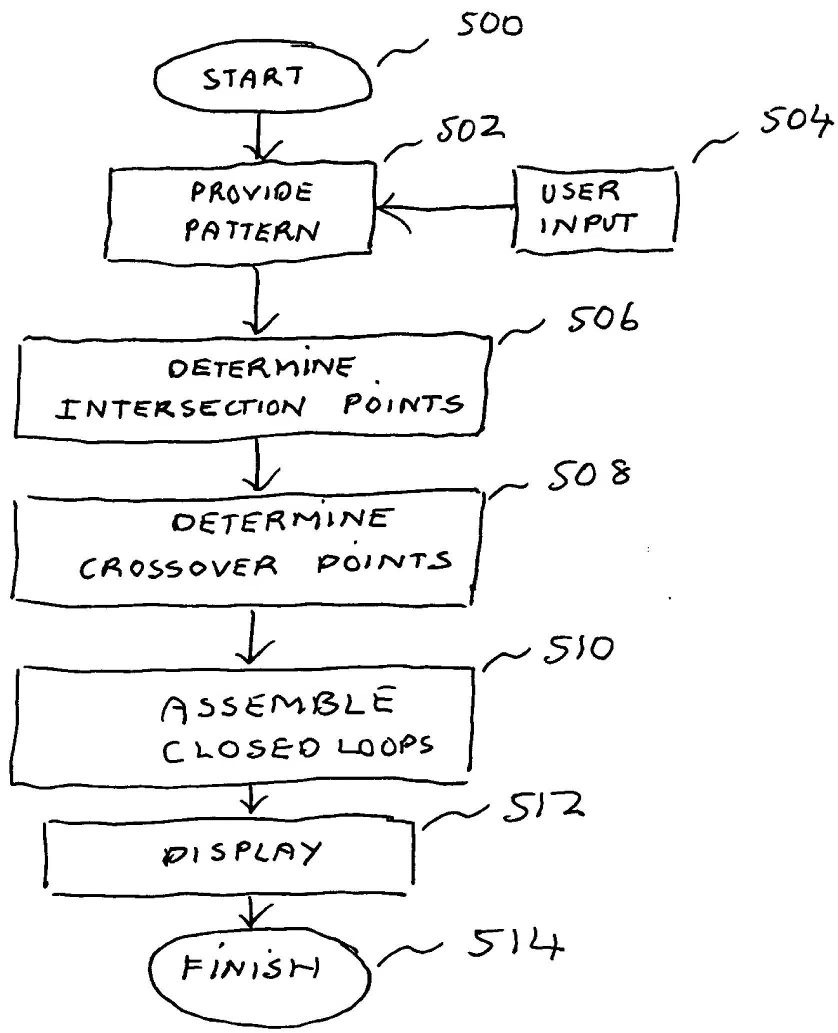
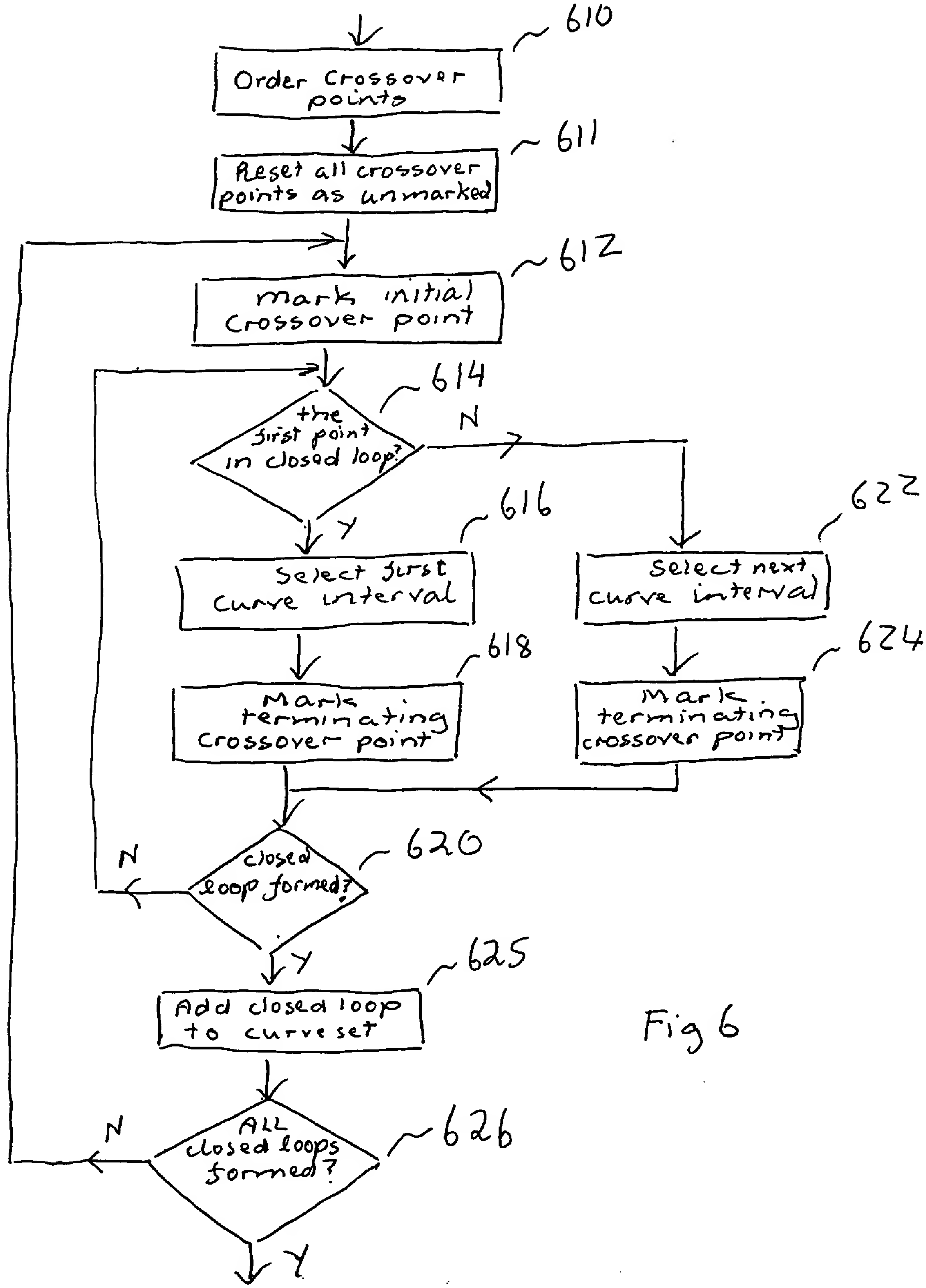

500
START
502
PROVIDE PATTERN
504
USER INPUT
506
DETERMINE INTERSECTION POINTS
508
DETERMINE CROSSOVER POINTS
510
ASSEMBLE CLOSED LOOPS
512
DISPLAY
514
FINISH

FIG. 5



610
Order Crossover points
611
Reset all crossover points as unmarked
612
mark initial crossover point
614
the first point in closed loop?
N
Y
616
Select first curve interval
622
Select next curve interval
618
Mark terminating crossover point
624
Mark terminating crossover point
620
closed loop formed?
N
Y
625
Add closed loop to curve set
626
ALL closed loops formed?
N
Y

Fig 6

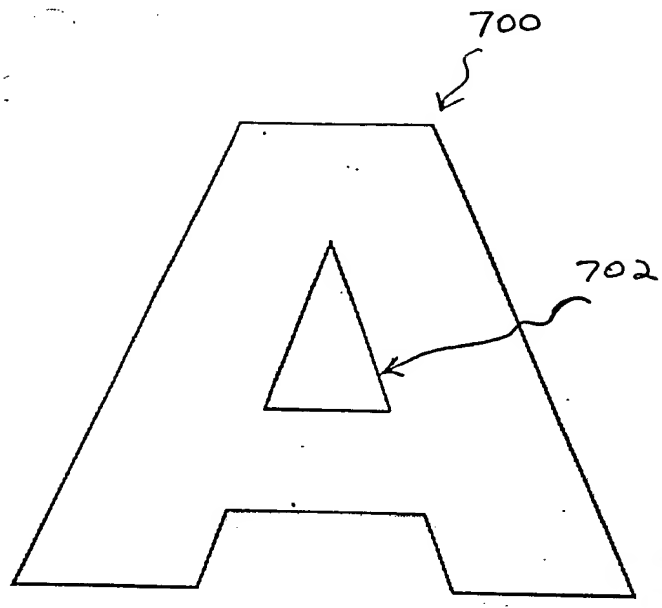


Fig. 7A

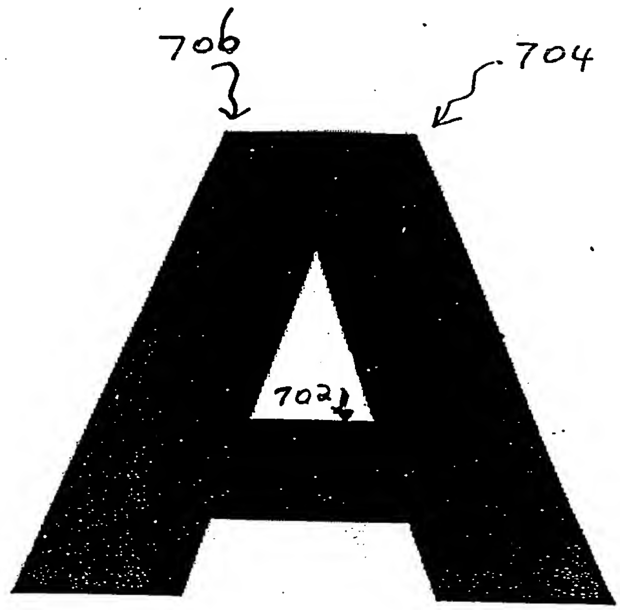
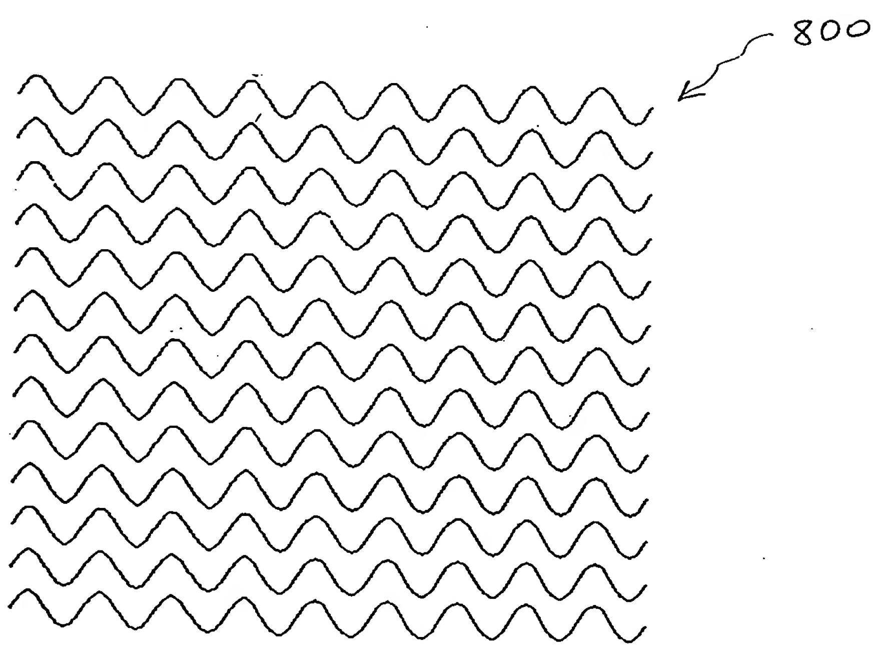


Fig. 7B

Fig. 8



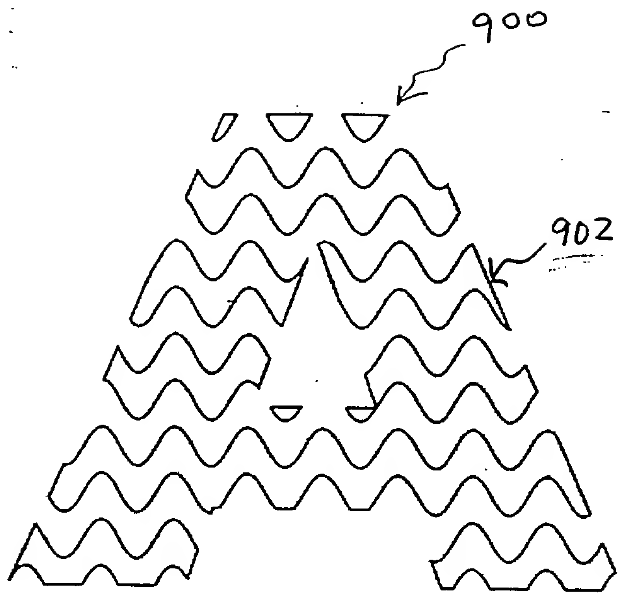


Fig. 9A

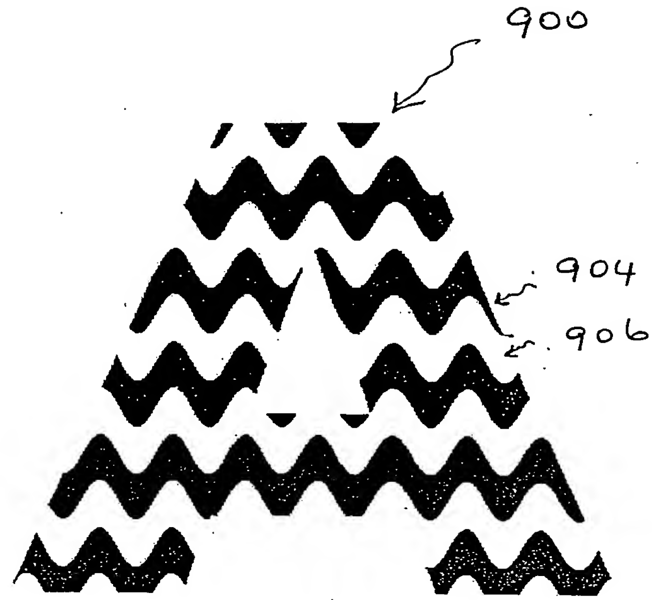


Fig. 9B

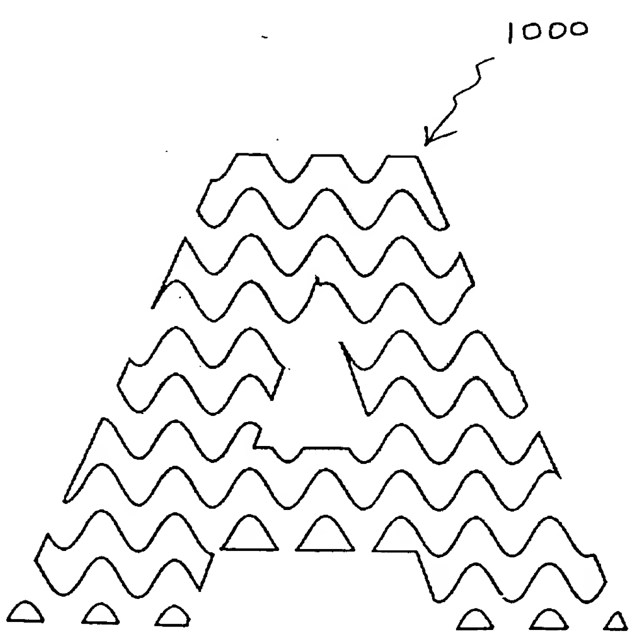


Fig. 10A

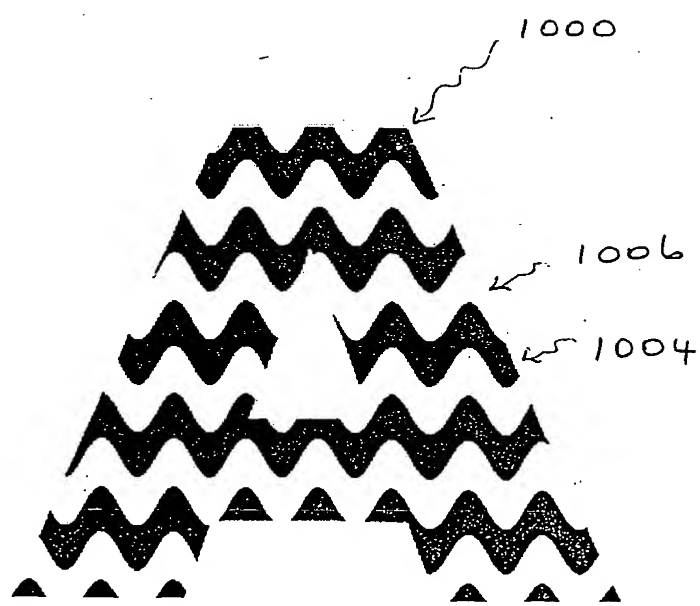


Fig. 10B

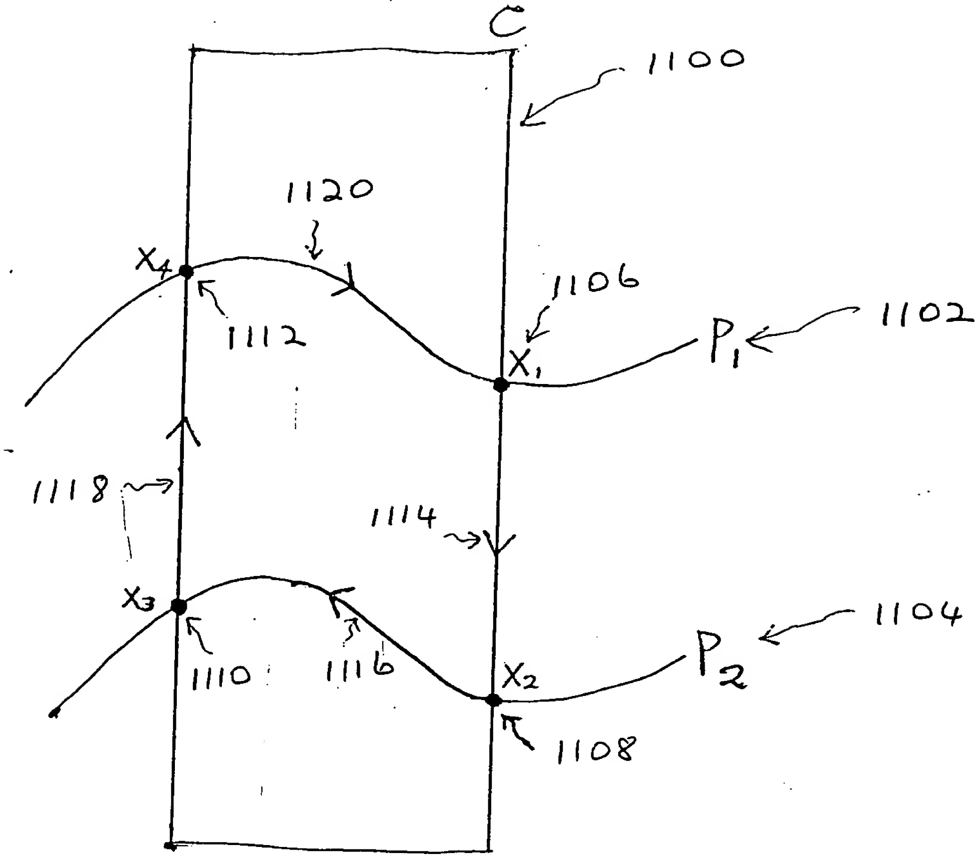


Fig. 11A

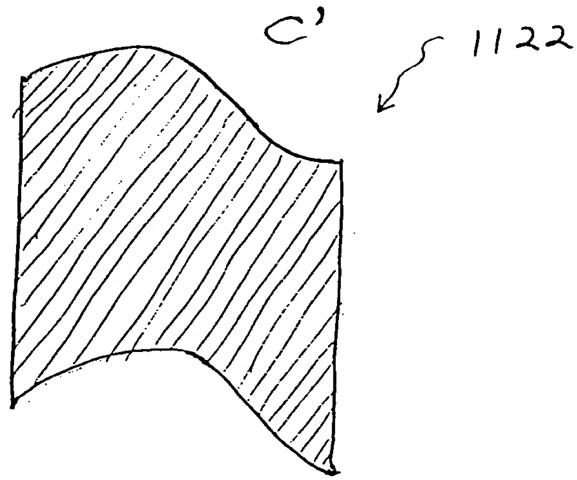


Fig 11B

Fig. 12

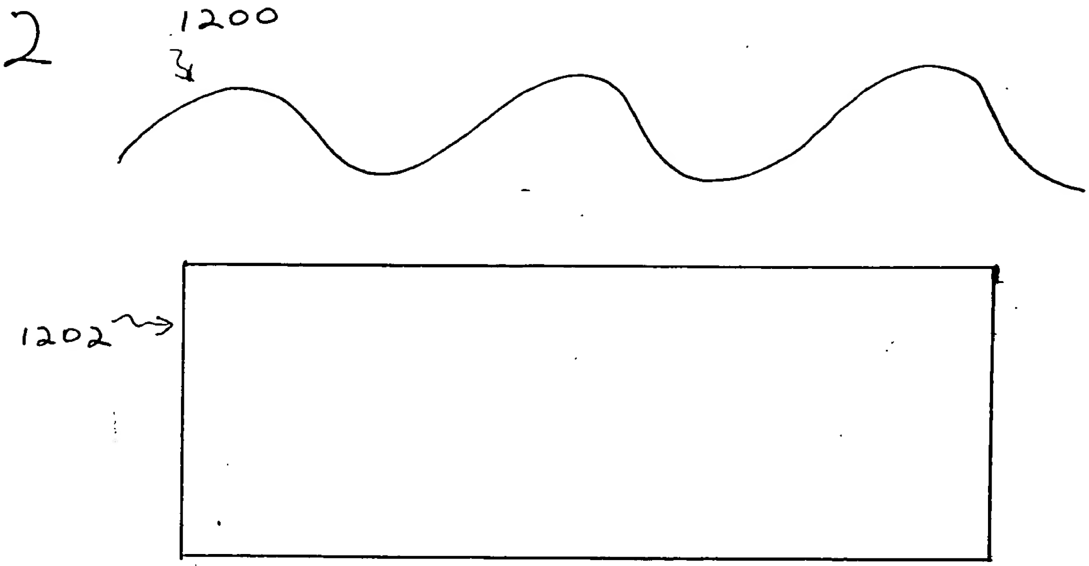


Fig. 13

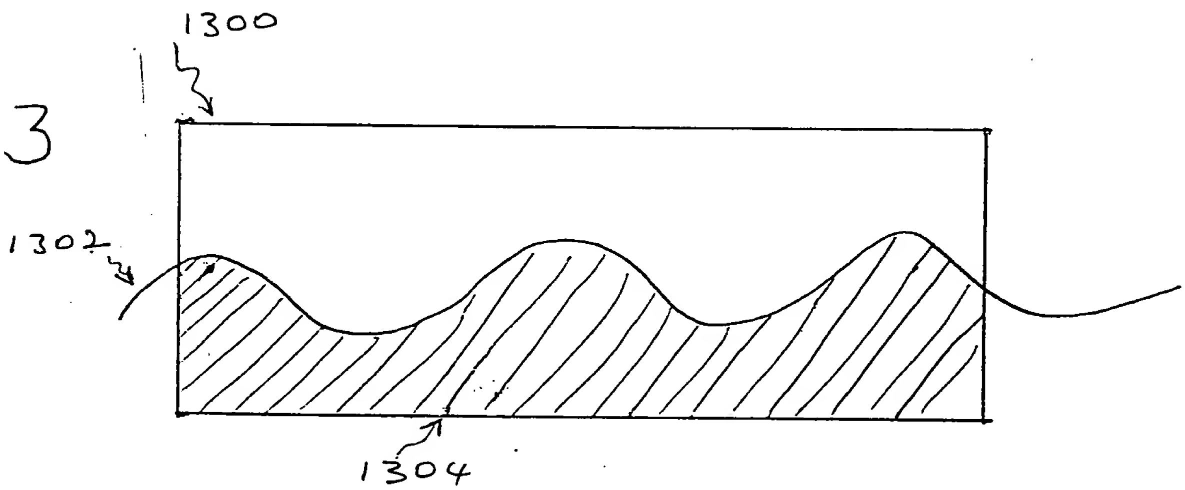
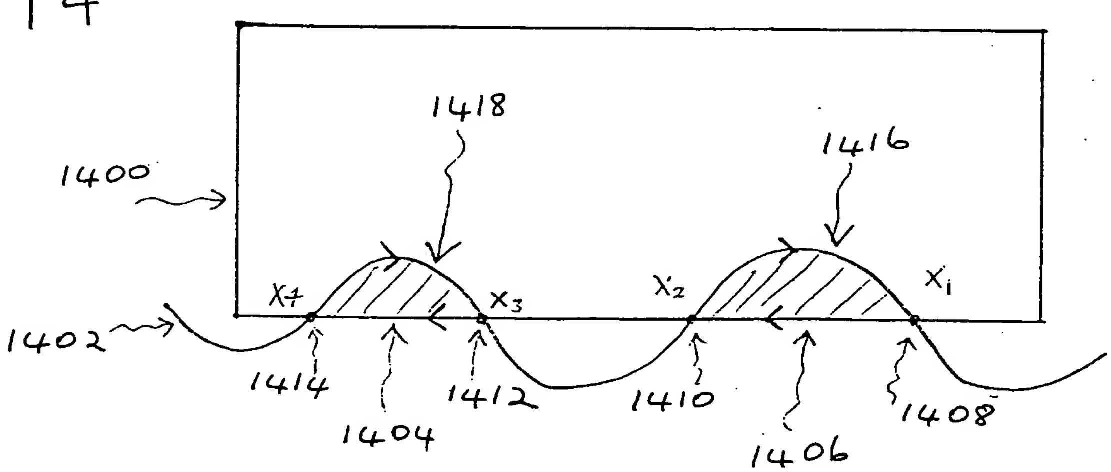


Fig. 14



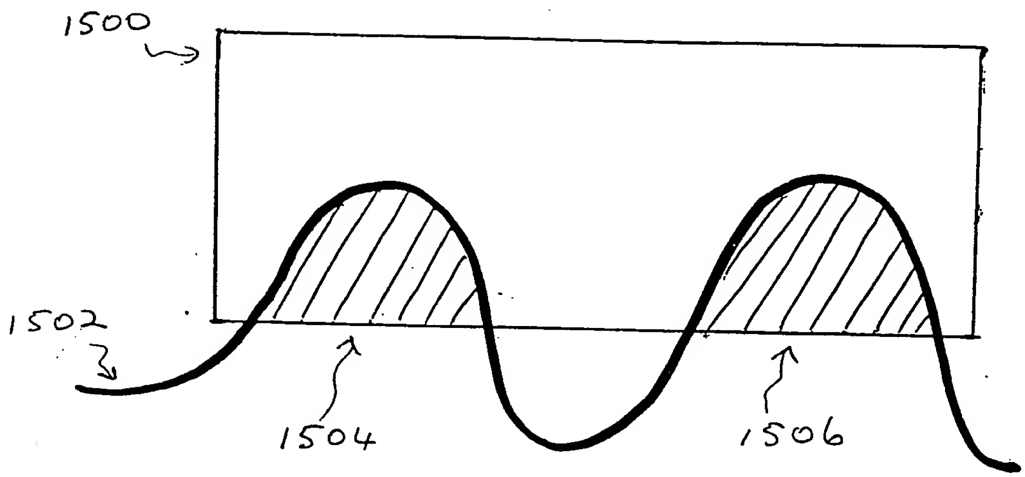


Fig. 15A

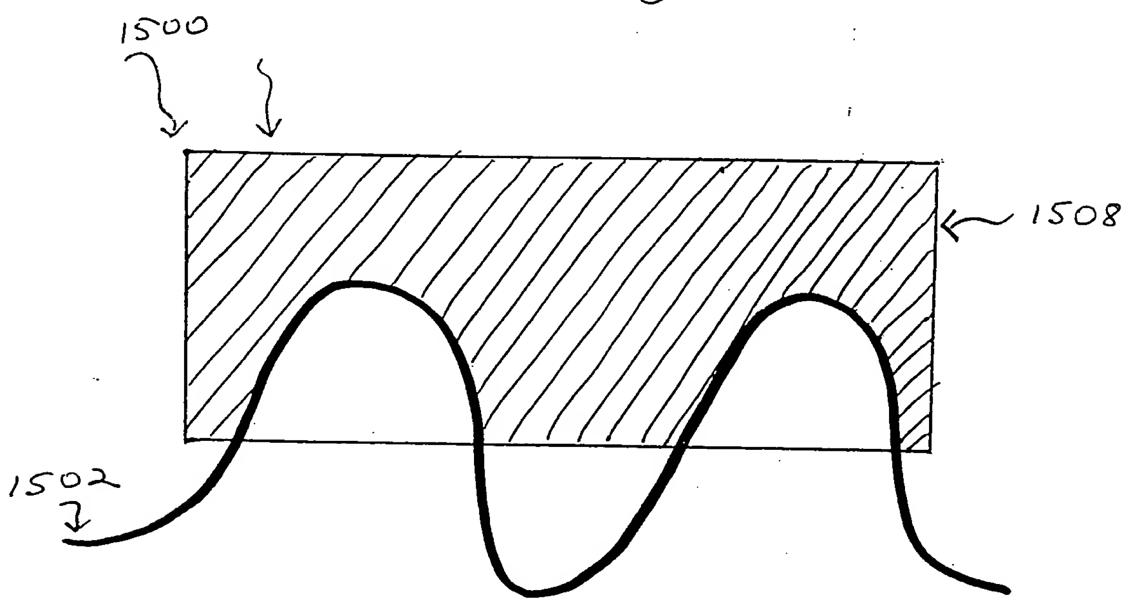


Fig. 15B

Fig. 16

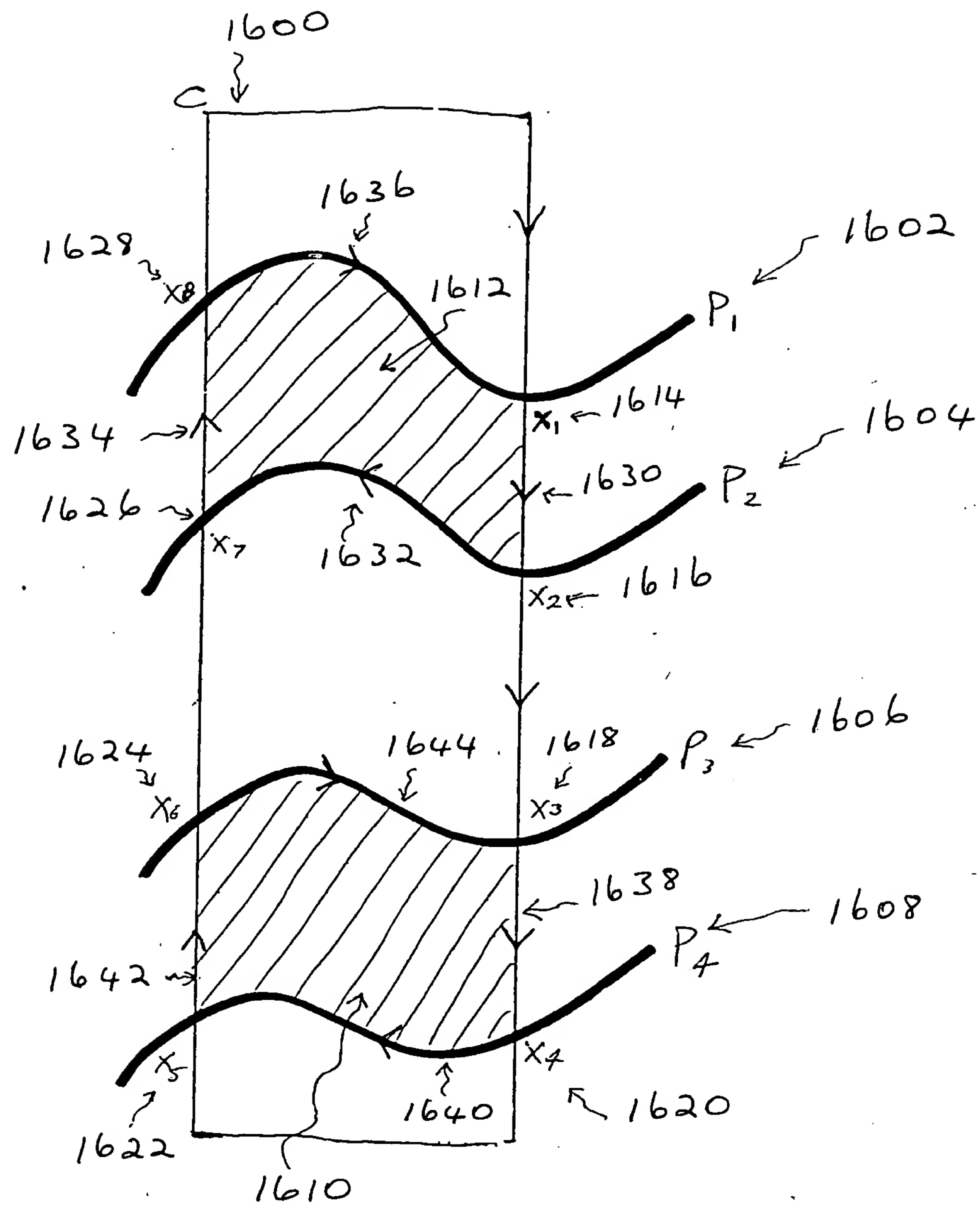
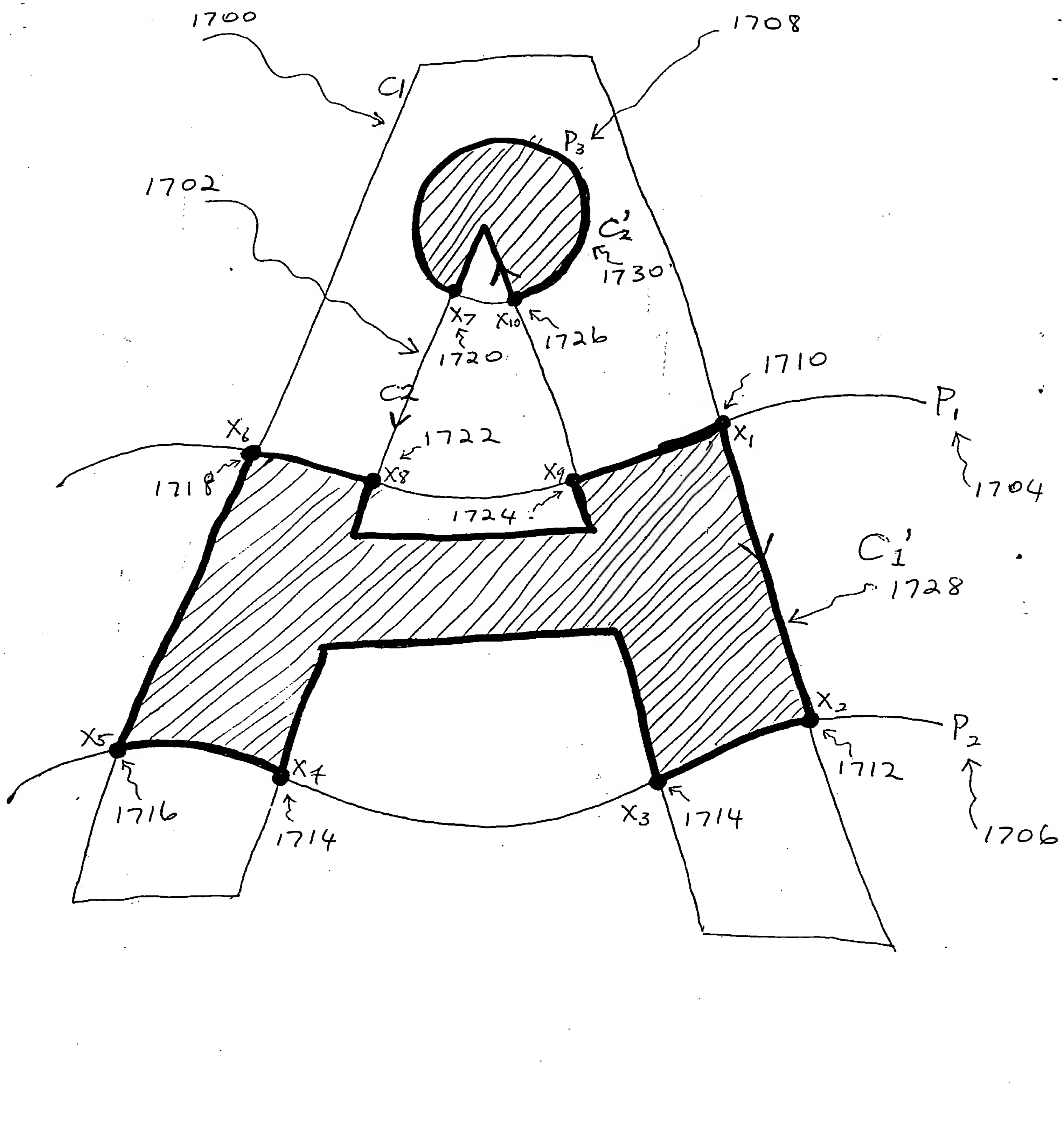

1600
C
1636
1628
X8
1612
1602
P1
1634
X1
1614
1604
P2
1630
1626
1632
X7
1616
X2
1624
1644
1618
1606
P3
X6
X3
1638
1608
P4
1642
X5
X4
1640
1620
1622
1610

Fig. 17


1700
1708
C1
P3
1702
C2'
1730
X7
X10
1726
1720
1710
C2
P1
1722
X6
X1
X8
X9
1704
1718
1724
C1'
1728
X2
P2
X5
X4
1712
X3
1714
1716
1714
1706

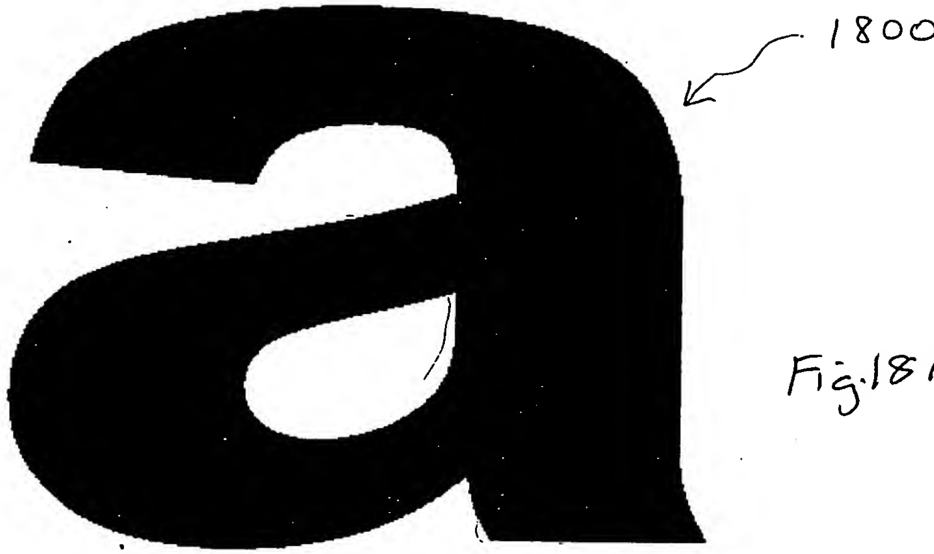


Fig. 18A

Fig. 18B

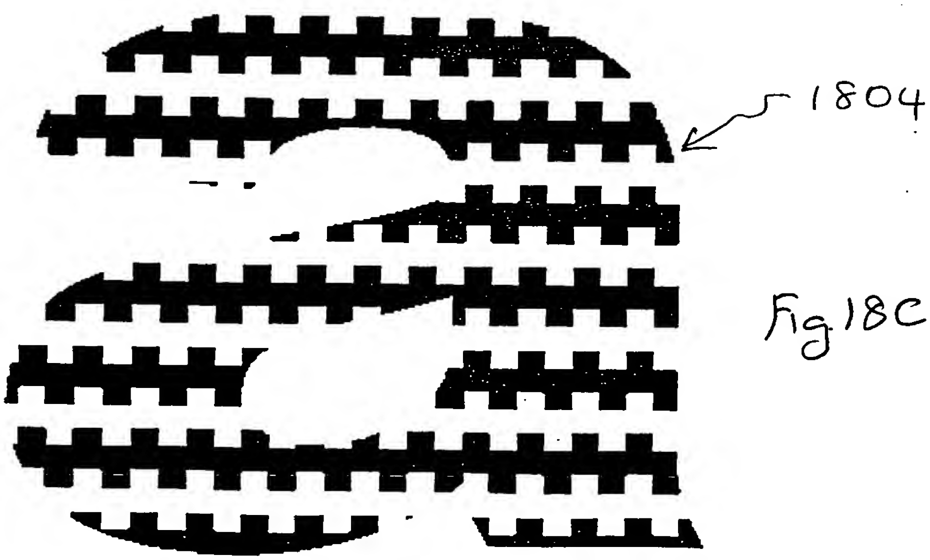


Fig. 18C

Fig. 19

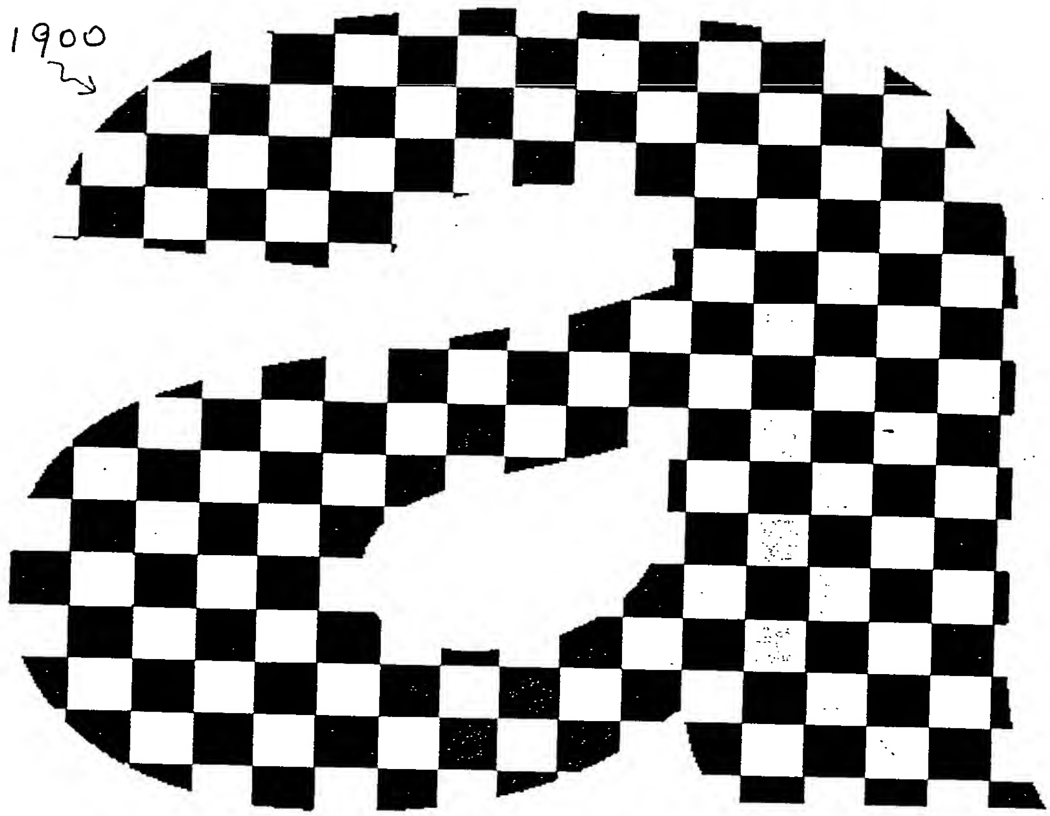
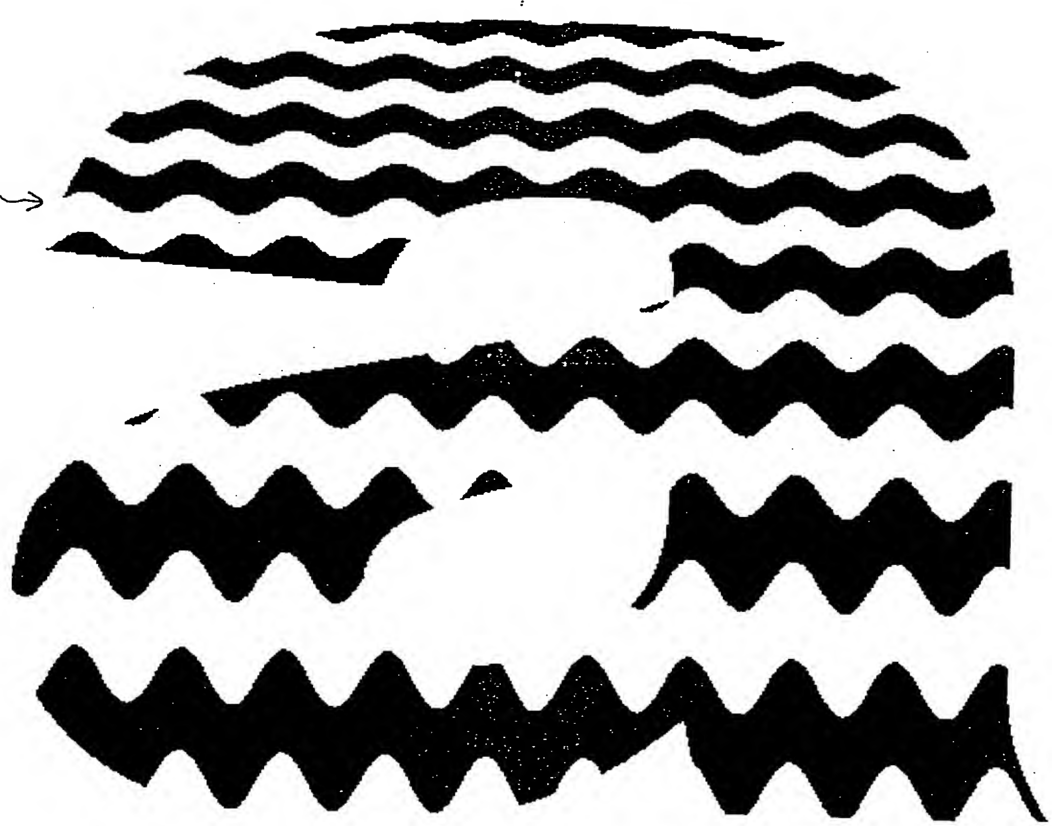


Fig. 20



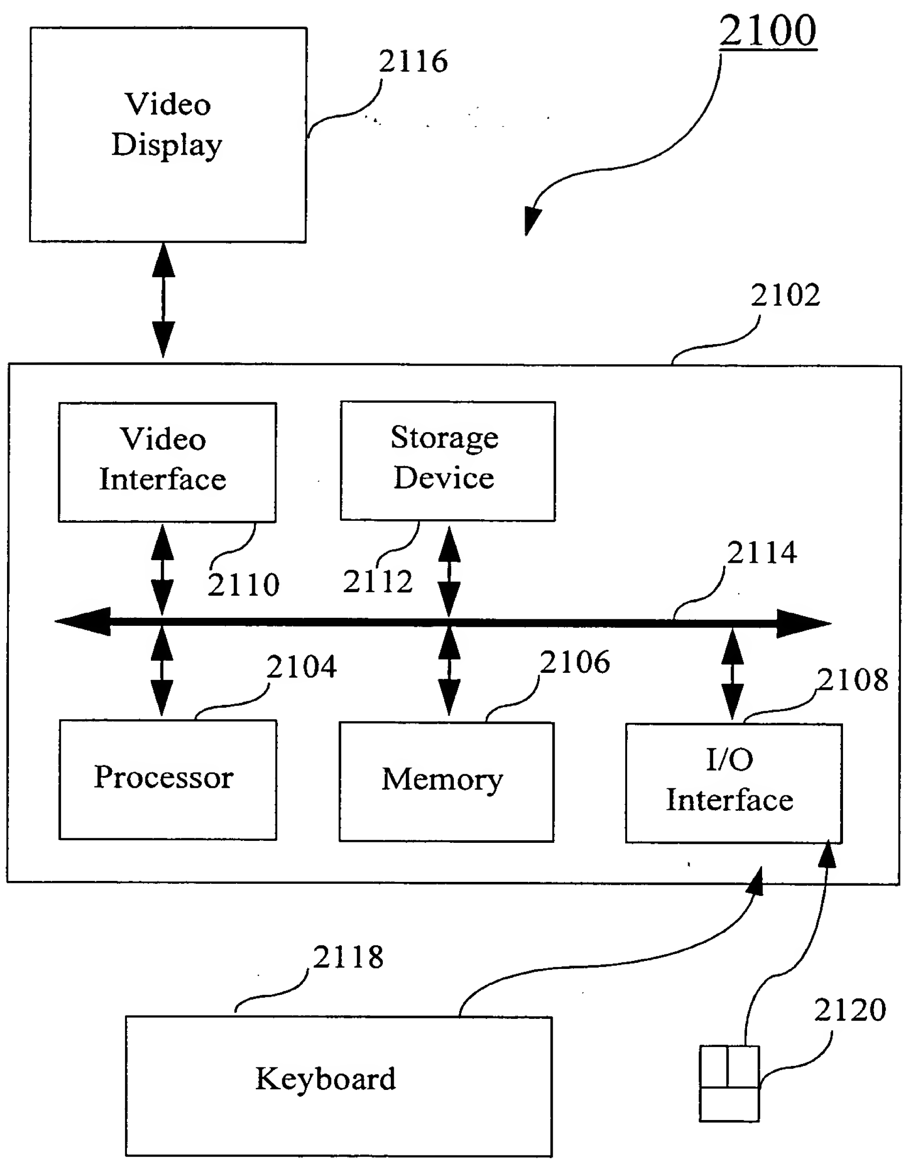

2100
2116
Video
Display
2102
Video
Interface
Storage
Device
2110
2112
2114
2104
2106
2108
Processor
Memory
I/O
Interface
2118
2120
Keyboard

Fig. 21